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AUTHOR Ferrigno, Carmelo F.; Wiltshire, Denise A.
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ABSTRACT

Hypermedia technology offers new opportunities for developing earth science teaching materials. During the past 3 years, the U.S. Geological Survey has conducted a series of research and development projects to assess the effectiveness of hypermedia technology in providing innovative teaching products for middle school students. The goal of this research is to develop interactive computer software that is based primarily on the visualization of earth processes to facilitate learning. As a result of the research, the U.S. Geological Survey has developed two hypermedia products that serv as prototypes of electronic teaching tools. Interdisciplinary teams were formed to design, implement, and test the educational hypermedia software products. The participation of teachers and students in the design and testing phases was critical to the success of the project. Standardized testing procedures were developed during the course of the project to ensure software quality. The combination of manual and automated testing procedures was essential to the success of product development. Preliminary results of the educational hypermedia study indicate that more stringent quantitative and qualitative evaluations of the products are needed. Producing multimedia educational tools for minimally-configured computers continues to pose problems for incorporating high-resolution animation, imagery, video sequences, and sound. The next phase of research conducted by the U.S. Geological Survey will focus on migrating from presentation-oriented hypermedia systems toward interactive applications that empower students with the capability to create their own multimedia notebooks. (Author)

Development and Evaluation of a Series of Hypermedia Educational Systems for the Earth Sciences

Carmelo F. Ferrigno & Denise A. Wiltshire
U.S. Geological Survey
12201 Sunrise Valley Drive, Mail Stop 801
Reston, Virginia 22091
E-Mail: ferrigno@sun4bta.er.usgs.gov

Abstract: Hypermedia technology offers new opportunities for developing earth science teaching materials. During the past three years, the U.S. Geological Survey has conducted a series of research and development projects to assess the effectiveness of hypermedia technology in providing innovative teaching products for middle school students. The goal of the research is to develop interactive computer software that is based primarily on the visualization of earth processes to facilitate learning. As a result of the research, the U.S. Geological Survey has developed two hypermedia products that serve as prototypes of electronic teaching tools. Interdisciplinary teams were formed to design, implement, and test the educational hypermedia software products. The participation of teachers and students in the design and testing phases was critical to the success of the project. Standardized testing procedures were developed during the course of the project to ensure software quality. The combination of manual and automated testing procedures were essential to the success of product development. Preliminary results of the educational hypermedia study indicate that more stringent quantitative and qualitative evaluations of the products are needed. Producing multimedia educational tools for minimally–configured computers continues to pose problems for incorporating high–resolution animation, imagery, video sequences, and sound. The next phase of research conducted by the U.S. Geological Survey will focus on migrating from presentation–oriented hypermedia systems toward interactive applications that empower students with the capability to create their own multimedia notebooks.

In 1991, the U.S. Geological Survey began a series of research and development projects to improve outreach to the pre-collegiate educational community. The goal of the outreach program is to develop a diverse approach to meeting the earth science information needs of the education community. Three program goals are currently defined:

- Materials development (traditional printed teaching packets)
- Experimental computer software applications
- Student–teacher activities, such as workshops and geologic field trips.

The U.S. Geological Survey began the initial computer software project in 1991 to develop an earth science computer system based on hypermedia technology. The objective of the research and development project was to design and implement a hypermedia educational system aimed at middle school students. The project resulted in the production of a hypermedia system known as *GeoMedia* (Wiltshire & Powell, 1993, p. 96) that presented a mix of information on the water cycle, earthquakes, and understanding maps. Each of the three modules contains animations, illustrations, text, a glossary of terms, and a reading list. The application was designed for Apple®[1] Macintosh® computers and developed using MacroMind® Director™ authoring software, which is produced by Macromedia, Inc.

[1] Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

Teacher Evaluations

GeoMedia was distributed on digital compact disc to earth science teachers in the United States. To date, approximately 1,700 discs have been distributed to educators willing to participate in the project by supplying evaluation comments. Each disc was accompanied by a reader response form that queried teachers on the following evaluation criteria:

- Was the material appropriate for grades 4–8?
- Did *GeoMedia* increase an interest in the earth sciences among students?
- How well did the application perform on your computer system?
- Was the system easy to use and was the supplied documentation helpful?

The project team created a database containing the responses prepared by recipients of the software. Preliminary analysis of the evaluation data show that five basic conclusions may be drawn:

- The material is appropriate for grades 4–8.
- The hypermedia presentation approach is appropriate for a wider range of grade levels than traditional text books.
- Student interest in the earth sciences was increased using *GeoMedia*.
- The performance was slow on Macintosh systems typically found in middle schools (Macintosh LC series).
- In spite of the limitations of system performance on minimally–configured Macintosh systems, students responded favorably to the hypermedia format.

The informal evaluation resulted in a low response by teachers (120 out of 1700 responded). The targeted response by the project team is 30 percent. Although only 7 percent of the teachers have responded to the evaluation form, some *GeoMedia* recipients have written to explain that the hypermedia system will be presented at teacher workshops conducted during the coming year. Another contributing factor to the low response may be that a self–addressed mailer was not included in the shipment with the digital compact disc and evaluation form. The project team plans to prepare follow–up correspondence to teachers coupled with the distribution of volume 2 in the series (*GeoMedia2*). In addition, the project team plans to confer with marketing research experts on how to improve the teacher evaluation questionnaire for the second volume of *GeoMedia*.

Scope of GeoMedia2

Favorable responses to *GeoMedia* from U.S. Geological Survey employees and the education community led to the development of a second hypermedia system on global environmental change. Again, the targeted academic level is middle school. The basic design metaphor of *GeoMedia2* is patterned after the original system (Evans, 1993, p. 69). *GeoMedia2* includes three modules on the carbon cycle, greenhouse effect, and monitoring environmental changes over time. The same graphical user interface is used with a few modifications based on teacher evaluations of *GeoMedia* (Figure 1). The modules each contain four sections: Animation, Elements, Glossary, and Further Reading. The Carbon Cycle module illustrates the movement of carbon through the environment and the effect of human interactions on the cycle. The Greenhouse Effect module explains a natural environmental process that traps heat in the lower part of the Earth's atmosphere to keep our planet warm enough to sustain life. In the Time & Change module, students learn about the geologic history of the Earth and the evolution of living organisms. *GeoMedia2* focuses on the many changes that have occurred throughout the 4.5 billion history of the Earth in the physical, chemical, geological, and biological characteristics of the planet.

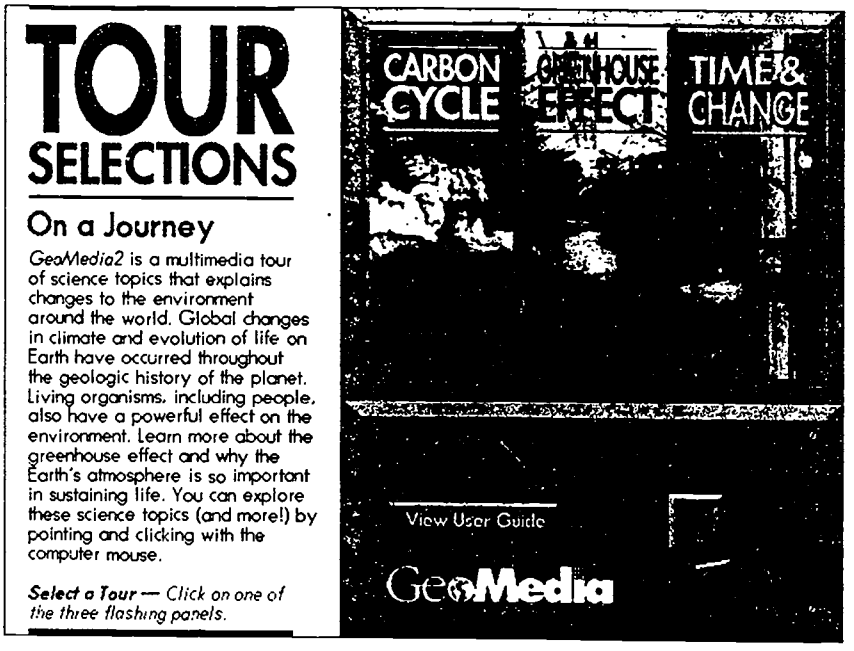

Figure 1. Computer screen from *GeoMedia2* showing table of contents.

Development Issues

Once again an interdisciplinary project team was assembled with a mix of skills in writing, animation production, graphic design, and computer systems analysis to develop *GeoMedia2* (Wiltshire & Ferrigno, 1993, p. 550). Scientists with expertise in global environmental change served as advisors to the project team. Teachers and students played a more active role in the conceptualization phase of the production of *GeoMedia2*.

A workshop was held at the National Science Teachers Association annual convention midway through the project to incorporate suggestions by teachers relating to subject coverage and system functionality. As a result of the workshop, the global change glossary was expanded to include pronunciations of terms. The third module contained in *GeoMedia2* was significantly modified to include more information on geologic time scales and the relationship between environmental changes and species evolution.

Based on discussions with teachers regarding curriculum and subject coverage in *GeoMedia2*, the recommended academic level for this second volume was changed to grades 6–9. Unlike *GeoMedia*, which addresses well established earth science topics, the material presented in *GeoMedia2* is inherently more complex. The information on topics, such as global warming and depletion of the ozone layer, is based on theories currently undergoing testing and analysis. The scientific debate surrounding issues related to global environmental changes contributed to the difficulty in translating theories to accurate material appropriate for the age group. The complexity of the topics also contributed to the longer length of the animations compared to the first volume of *GeoMedia*.

The underlying file structure of *GeoMedia2* was modified to increase performance of the application. The animation and sound files were divided into many small files that load into memory at a more rapid rate. Hence, performance on minimally–configured computers is improved. A file–naming convention was implemented to improve software development and to facilitate testing procedures. The project team also developed typographic standards to improve consistency in text-based navigation instructions.

Additional printing options from within the *GeoMedia2* user interface were added in response to teacher evaluations requesting functionality improvements. The capability to print the *GeoMedia2 User Guide* and student reading lists from within the application was added, thus eliminating the need for the user to initiate printing from the desktop of the digital compact disc (Figure 1). Many of the evaluation responses indicated that teachers did not notice the user guide on the desktop of the digital compact disc. Some teachers

confused the configuration information printed on the insert to the compact disc jewel case with the user guide. The option to print the reading lists from within *GeoMedia2* was added to the Further Reading section of each module (Figure 2).

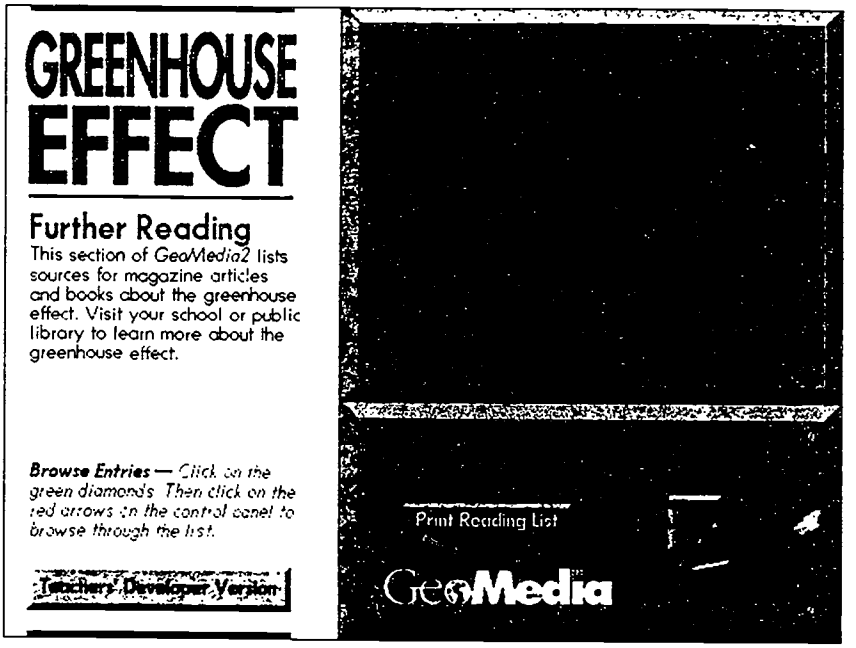

Figure 2. Computer screen from *GeoMedia2* showing print option.

Another user interface design issue related to problems with exiting the *GeoMedia* application. The original purposes of the *GeoMedia* application were for use in the U.S. Geological Survey Visitors Center in a kiosk and for presentations at outreach activities, such as Earth Day celebrations. The design team intentionally omitted an icon to represent the quit function to guard against students escaping from *GeoMedia* to the Macintosh desktop. Two keyboard sequences are available for exiting the application and are described in the user guide. Although the method for exiting the program was not changed for *GeoMedia2*, specific instructions on exiting the application were added to the printed material contained on the insert to the compact disc jewel case.

To further improve functionality, the project team investigated the QuickTime™ system extension for use in *GeoMedia2* as a compression algorithm for video sequences and animations. QuickTime can also be used to compress large images, which reduces the amount of memory required to store and display images (Don, 1992, p. 52). Three factors that affected use of QuickTime in *GeoMedia2* include: (1) the system extension is proprietary and must be obtained separately from the Macintosh operating system, (2) the system extension must be installed in the user's configuration file (Macintosh System Folder), and (3) the image resolution and frame rate for video sequences and animations are low. Use of QuickTime in *GeoMedia2* is restricted to two video sequences that show global climate models generated by supercomputers and digitized from a video tape. If the user does not have QuickTime installed, a still image appears instead of a video sequence. The optional display of video sequences offers flexibility when developing hypermedia applications for both low– and high–performance microcomputers. As noted above, replacing video sequences with still images or animated sequences ensures reliable performance on minimally–configured computers.

Testing Procedures

Extensive colleague reviews and functionality tests were required to ensure the scientific accuracy of the information and the reliability of the application. An advisory group of scientists from the U.S. Geological

Survey conducted colleague reviews of both *GeoMedia* applications to verify the accuracy of the information.

Teachers played a more prevalent role in the beta testing process of *GeoMedia2* than for the first volume. In addition, a revised testing procedure was developed for *GeoMedia2* to improve the ability to duplicate or trace errors, such as incorrect links. The original testing procedure was based on an outline of links found in the main screen for each module. This procedure was completely manual and marginally satisfactory for conducting reliable tests. For example, if an error such as an incorrect link was discovered, it was difficult to retrace the path taken through the application because no manual or automated procedure recorded this path.

Because of time constraints and limitations of the authoring system used for *GeoMedia2*, no automated testing procedures were developed. However, an improved testing document was developed to include a snapshot of each screen of the application. All navigation icons and links were represented in the testing document along with tables to represent paths through the information. The tables served as checklists for the technical project staff and teachers conducting the beta tests. The outline used for beta testing volume 1 of *GeoMedia* did not provide a formal mechanism for indicating text changes. Snapshots of each screen provided in the *GeoMedia2* testing document allowed reviewers to easily note text changes. The expanded testing document provided an excellent method for correcting errors in the text and for consistently documenting software problems. The testing document continued to provide a marginally acceptable method for testing non-sequential navigation patterns. Hence, the testing procedure remained linear.

To thoroughly test the application in a non-linear method, an automated procedure is required. Using an automated approach for capturing navigation data provides an accurate report of the reviewer's path through the information. The navigation data or audit trail can facilitate the testing and correction process (Beasley, 1992, p. 466).

Future Plans

The U.S. Geological Survey plans to continue assessing the effectiveness of hypermedia technology in teaching earth science concepts. Plans are in place for developing a third educational system that provides students with an interactive application that extends beyond a presentation format by empowering the student to create interpretations of the information. While *GeoMedia* has received favorable review comments, a need exists to develop a hypermedia system that enables students to navigate through a non-sequential arrangement of information and further participate in the creative process by authoring their own multimedia reports (Kinnaman, 1990, p. 46).

The proposed application will explain earth science processes within a geographically–referenced hypermedia system. Students will explore earth science topics by selecting geographic regions that are notable for extreme (unique) hydrologic or geologic conditions. The approach to the information will be by way of maps and satellite images instead of topics from a table of contents, as in *GeoMedia*.

Summary

As a result of a three–year study, the U.S. Geological Survey has developed two hypermedia products that serve as prototypes of electronic teaching tools. Interdisciplinary teams are needed for design and conceptualization of the products in addition to testing. The participation of teachers and students in the design and testing phases is also critical to the success of the project. Standardized testing procedures are required to ensure software quality. The combination of both manual and automated testing procedures is essential to the success of product development. Preliminary results of the educational hypermedia study indicate that more stringent quantitative and qualitative evaluations of the products are needed. Producing multimedia educational tools for minimally–configured computers continues to pose problems for incorporating high–resolution animation, imagery, video sequences, and sound. The U.S. Geological Survey plans to migrate from presentation–oriented hypermedia systems toward interactive applications that empower students with the capability to create their own multimedia notebooks.

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